

METHOD AND APPARATUS FOR PERFORMING BANDEDGE EQUALIZATION

CROSS-REFERENCE TO RELATED APPLICATION

5 This non-provisional U.S. national application, filed under 35 U.S.C. §111(a) claims, under 35 U.S.C. §119(e)(1), the benefit if the filing date of provisional U.S. application no. 60/019,308, filed under 35 U.S.C. §111(b) on June 7, 1996.

FIELD OF THE INVENTION

10 The invention relates to digital information transmission systems. More particularly, the invention relates to improved timing recovery circuitry in digital information transmission systems that employ bandedge timing recovery.

BACKGROUND OF THE DISCLOSURE

15 A conventional digital information transmission system contains a data source, a transmitter, a transmission medium, and a receiver. Illustratively, in a digital television system, the data source is a digitized audio-video signal, the transmitter contains a plurality of application
20 encoders (e.g., a video signal encoder, an audio signal encoder, and a system control information encoder), a transport encoder for packetizing and multiplexing the encoded signals and an M-ary quadrature amplitude modulation (QAM) modulator. The transmission medium is typically a cable network or wireless path.

25 The receiver in a digital television system contains a demodulator for demodulating the QAM signal, a transport decoder for depacketizing and demultiplexing the encoded signals, a plurality of application decoders, and a presentation device for displaying the information from the data source to a user, e.g., the presentation device can be a conventional television. The
30 demodulator produces a serial baseband digital signal (a bit stream containing packetized and multiplexed digital information). As is well-known in the art, the demodulator accomplishes carrier recovery, signal equalization, packet synchronization and the like, to generate a useful

00869559-060597

5
10

15

20

25

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows a high level block diagram of a receiver in accordance with the invention; and

FIG. 2 shows a detailed block diagram of the bandedge equalizer of the present invention.

25 To facilitate understanding, identical reference numerals have been used, where possible, to designate identical elements that are common to the figures.

DETAILED DESCRIPTION

FIG. 1 depicts a high level block diagram of a receiver 100 in accordance with the teachings of the present invention. The receiver shall be described in the context of a conventional digital television application.

However, from the following disclosure, those skilled in the art will understand that this form of inventive receiver can be used in any digital data transmission system that uses a bandedge timing recovery technique.

The receiver 100 contains a tuner 102, a demodulator 104, a
5 transport decoder 108, one or more application decoders 110, and one or more presentation devices 112. Typically, the tuner 102 (also known as an RF/IF front end), located prior to the demodulator 104 and connected thereto, selects one channel of information for receipt from multiple available channels carried by a transmission medium such as a cable
10 network or wireless transmission system.

The input signal to the demodulator 104 is a modulated analog signal, e.g., an M-ary QAM signal (where M is typically 16, but can be 32, 64, 256 and the like), centered at a low intermediate frequency (IF), e.g., a 5 MHz IF having a 6 MHz bandwidth. Although discussed in relation to a
15 QAM signal, those skilled in the art will understand that the invention can be utilized with any other form of modulation, e.g., vestigial sideband (VSB), offset QAM (OQAM) and the like. The demodulator 104 demodulates the input signal to generate a digital bit stream represented by a series of signal samples, where each sample is a byte of digital data
20 representing a sample of a channel symbol. This digital data contains encoded and compressed audio and video signals and system control information. To facilitate accurate input signal sampling, the demodulator contains the bandedge equalizer 116 of the present invention as well as a conventional bandedge timing recovery circuit 106 for producing
25 substantially jitter-free timing signals. There are many such bandedge timing recovery techniques available in the art, all of which will be improved using the bandedge equalizer of the present invention.

The demodulated signal is then sent to the transport decoder 108 wherein a transport timing synchronization signal is generated from the
30 transmitter timing information contained in the bit stream. The transport decoder 108 depacketizes and demultiplexes the data packets as well as decodes appropriate system control information. The data from the packets

2025 RELEASE UNDER E.O. 14176

is transferred to an appropriate application decoder 110, e.g., video data is sent to an MPEG video decoder, audio data is sent to an MPEG audio decoder, and system control information is sent to one or more control signal decoders. The applications ultimately produce information that is presented to a user on a presentation device 112 such as a conventional television, computer terminal, and the like.

FIG. 2 depicts a detailed block diagram of the demodulator 104 containing the bandedge equalizer 116 of the present invention. The inventive bandedge equalizer corrects amplitude differences in the upper and lower bandedge signal strength. As such, the bandedge timing recovery circuit 106 is not affected by a bandedge amplitude imbalance.

As the QAM signal is analog, the received QAM signal is first sampled by an (A/D) converter 200 which converts the input signal into a digital data stream. Optimal sample timing for the A/D converter is provided by the bandedge timing recovery circuit 106. Within this data stream are digitized samples of information containing audio, video and system control. If the incoming signal had suffered some level of asymmetric attenuation during transmission, any or all of these signals may have been altered. Since system control signals contain important system timing information, the receiver's ability to process the output signal may be compromised as a result of the signal attenuation.

Following the A/D converter 200, the demodulator further contains a quadrature demodulator, 202, the bandedge equalizer 116, and a conventional equalizer and quantizer circuit 204. The quadrature demodulator 204 produces an in-phase (I) and quadrature phase (Q) signal components from the sampled input signal. The I and Q components are bandedge equalized (balanced) by the bandedge equalizer 116 to ensure that both bandedges of the I and Q components have substantially equal amplitude. The bandedge equalized signal is then conventionally equalized to suppress intersymbol interference and quantized to produce a digital symbol stream. The bandedge equalization ensures that a bandedge timing recovery technique operates properly, i.e., substantially jitter-free.

a



the instantaneous magnitudes of the negative and positive bandedge signals. These signals form a minuend and subtrahend for a subtractor 326. Specifically, the negative bandedge magnitude signal forms the subtrahend and the positive bandedge magnitude signal forms the minuend. The difference value produced by the subtractor is a preliminary adjusting factor ω which represents the difference in magnitudes between the upper and lower bandedge signal strengths. The preliminary adjusting factor ω forms the input to the loop filter 328 (a low pass filter). The output of the loop filter 328 is the final adjusting factor α . The final adjusting factor α is applied to the pre-equalizers 300 and 302 to balance the I and Q components of the incoming demodulated signal which is then processed by the remaining receiver circuitry. The pre-equalizer has the following

the lower bandedge frequency, the pre-equalizer attenuates the ^{higher} lower
 20 bandedge frequency signal by an amount (α) that is proportional to the
 signal difference (ω). If the converse occurs, i.e., lower bandedge signal
 larger than the upper bandedge signal, then the pre-equalizer attenuates
 the lower bandedge signal. As a result, the bandedge signals used by a
 downstream bandedge timing recovery technique have substantially equal
 25 amplitudes. Consequently, the timing recovery is not impacted by a
 bandedge imbalance at the input of the receiver.

30 balanced bandedge signals.

Although various embodiments which incorporate the teachings of the present invention have been shown and described in detail herein, those skilled in the art can readily devise many other varied embodiments that still incorporate these teachings.

265090" 68569880